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FINAL REPORT

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COMPARISON OF ALTERNATIVE MECHANICAL AND CHEMICAL TOP-KILL METHODS TO ACHIEVE OPTIMUM QUALITY AND ECONOMICS OF SEED POTATO PRODUCTION

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Final Report

Comparison of Alternative Mechanical and Chemical Top-Kill Methods to Achieve Optimum Quality and Economics of Seed Potato Production

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1. Summary

Seed potato is a high value crop with considerable potential for Saskatchewan. However, input costs can be $5,000/ha ($2,000/ac), thus cost effective management is required to optimize returns. Top-killing is an important aspect of seed potato production especially with late maturing cultivars under relatively cool, short growing seasons. Desiccation using Reglone alone can be slow and costly; therefore, questions have arisen about the potential of using mechanical processes like vine shredders as a complementary strategy.

In the fall of 2000 and 2001, the Prairie Agricultural Machinery Institute (PAMI) and the Canada Saskatchewan Irrigation Diversification Centre (CSIDC) conducted a project for the Saskatchewan Seed Potato Growers Association (SSPGA). The project compared two different styles of vine shredders to determine their performance and ability to optimize seed potato quality and yield when used in combination with various desiccant treatments.

Tests were conducted on seed potato crops just east of the CSIDC site. A European style AMAC shredder was compared to an American style Alloway shredder. Engineering, agronomic, and financial comparisons were performed.

Engineering comparisons of the Alloway and AMAC machine suggested there were no differences between the work rate of the two machines when used to cut four rows on a pass. The AMAC appeared to do a more visibly desirable job of cutting the vines and it had lower power requirements.

Agronomic comparisons suggested little or no difference between any of the treatments. Also the visible differences observed between the two machines in quality of vine cut did not appear to translate into any difference in yield.

Financial comparisons showed that the Alloway had a slightly higher operating cost, primarily because it required a larger tractor. Also the Flail/Reglone treatment was the least costly of the four treatments.

Thus, since the Flail/Reglone treatment was the least cost operation and showed no reduction in yield or in other agronomic performance data, it has merit as a method to Top-Kill Seed Potatoes.

The Growers have seen considerable merit in this multi-discipline project and have expressed interest in a similar comparison of Potato Harvester equipment. PAMI and CSIDC will pursue such a project.

2. Technical Report

2.1 Background

The concept of Northern Vigor™ and the favourable climatic conditions makes Saskatchewan a high-quality seed potato producer. Saskatchewan is becoming an important player in the seed potato industry in the domestic and offshore markets. To meet this demand, seed potato production is expanding in Saskatchewan. Further information on Northern Vigor is provided in **Appendix I**.

Producing high-quality potatoes requires appropriate management practices that include: (i) production agronomy, (ii) pest and disease control, (iii) harvesting, and (iv) storage management. Most of the harvested crop is stored for varying lengths of time before marketing. Seed potatoes are stored for the longest period as they are marketed during the spring of the following year. Disease-free mature tubers with good skin set and minimal mechanical damage are better suited for long-term storage. Such tubers are considerably more resistant to bacterial and fungal diseases, as infections through wounds are minimized. Early-maturing cultivars, e.g. Norland, die down naturally and can be harvested with minimal pre-harvest operations. By contrast, mid-season (Russet, Norkotah, Shepody) and late-season (Russet Burbank, Ranger Russet) cultivars should be "top-killed" (i.e. vine killing) prior to harvest to induce maturity and accelerate skin set. Pre-harvest top-killing has several added advantages. These include: disease control (stop spread of fungal spores), reduced insect infestation (late-season spread of viruses through aphids), tuber size control, stabilization of tuber solids, less trash removal, increased harvest speed, and facilitation of smoother harvest by eliminating plugging and easier tuber separation from vines.

Top-killing can be achieved through chemical and mechanical means or a combination of both. Mechanical methods include:

1. Vine Pullers: Pulls the stolon from the tuber. Most pullers are equipped with skids to prevent tubers from being lifted off the ground.
2. Rollers: They crush the stems and flatten the vines to accelerate drying.
3. Flails: Cuts and removes vines instantaneously. They have several advantages, including even distribution of vine residue in the field, initiating tuber maturation immediately, and promoting tuber maturation.

Flailing is becoming increasingly popular amongst seed and commercial potato growers in North America including Saskatchewan. There are several types of flails on the market with varying levels of efficiency and power requirements. The degree of success with flailing depends on the vigour of the crop, vine mass, and the efficiency of the machine. With late maturing vigorous potato cultivars, it is possible to improve the performance of flailing through partial desiccation with chemicals prior to flailing.

Potato growers in Saskatchewan are considering flailing as a top-kill method for seed and consumption potatoes. No information is available comparing performance efficiency and economic considerations for selecting flails. This study is designed to compare two types of flails in relation to work rate, quality of work, power and energy requirement, durability, and cost effectiveness in association with chemical desiccants for late-maturing potato cultivars.

2.2 Objectives

This project compared eight different top-kill treatments over a two-year period to determine the most cost-effective treatment that yields optimum seed quality and yield. The treatments compared an Alloway vine shredder made in the USA to an AMAC vine shredder made in Europe. Different Reglone application rates were also used in the treatments.

2.3 Project Procedure

This study was done on Russet Burbank potato fields in the Outlook area. This is one of the most popular cultivars for seed and commercial markets. This cultivar was selected due to its profuse vine growth and late-maturing characteristics. The potato crop is being grown under irrigation using standard management practices.

Comparisons occurred during the seed potato harvest of 2002 and 2001. Tests consisted of agronomic and engineering comparisons of the eight different treatments **(Table 1)**.

Table 1. Treatments.

Stage 1	Stage 2	Stage 3	Treatment Identifier	
			AMAC	Alloway
Flail + Reglone 1.3 L/ha (0.5 L/ac) on the same day or the next day			FR (M)	FR (L)
Reglone 2.0 L/ha (0.8 L/ac) + Flail after partial vine kill (5 to 7 days)	Reglone 2.0 L/ha (0.8 L/ac) on the same day		RFR (M)	RFR (L)
Reglone 2.0 L/ha (0.8 L/ac)	Reglone 2.0 L/ha (0.8 L/ac) after partial vine kill	Flail after 5 to 6 days	RRF (M)	RRF (L)
Reglone 2.5 L/ha (1.0 L/ac)	Reglone 2.0 L/ha (0.8 L/ac)		RR (M)	RR (L)

The actual dates of occurrences are in **Table 2**.

Table 2. Date of Treatments.

Treatment	2000			2001		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
FR	Aug 29 & 30	--	--	Sep 11 & 12	--	--
RFR	Aug 30	Sep 11 & 12	--	Sep 12	Sep 18 & 19	--
RRF	Aug 30	Sep 12	Sep 26	Sep 12	Sep 19	Sep 25
RR	Aug 30	Sep 12	--	Sep 12	Sep 19	--

Engineering measurements determined work rate, quality of work, power requirements, operator's manual suitability, operator safety, and durability. Detailed measurements were conducted on grower's crops at the CSIDC sites. A special focus, due to grower's recommendations, was that a thorough assessment of durability be conducted. To accomplish this, PAMI used a combination of data from observed breakdowns in local growers' fields, as well as surveys of other vine shredder owners from other potato growing areas to determine the respective machine durability.

The agronomic measurements and assessments focused on seed potato quality were as follows:

- Plant sampling was based upon 1 m/row (3.3 ft/row) and three samples per treatment.
- Vine moisture content, tuber yield, size distribution, tuber weight, and specific gravity were measured.
- Stem end browning, bruising, storage loss, and disease incidence were observed.

Approval of the project occurred shortly before the project was to begin in 2000. A quick discussion occurred between PAMI, CSIDC staff, the Saskatchewan Seed Potato Growers, and the co-operators, and based on the discussion, the project began in haste. Most necessary data was collected in the fall of 2000. However, the power data obtained in that year had some gaps. In 2001, all power data was obtained so only the 2001 data was used for further analysis.

The European design shredder, an AMAC LK4 (**Figures 1** and **2**), was owned by John Konst, the American design Alloway Shredder was owned by Jim Massey for the 2000 test, and the Sask Valley Potato Corporation for the 2001 test (**Figures 3** and **4**). Copies of machine brochures are in **Appendix II**.

Figure 1. AMAC.

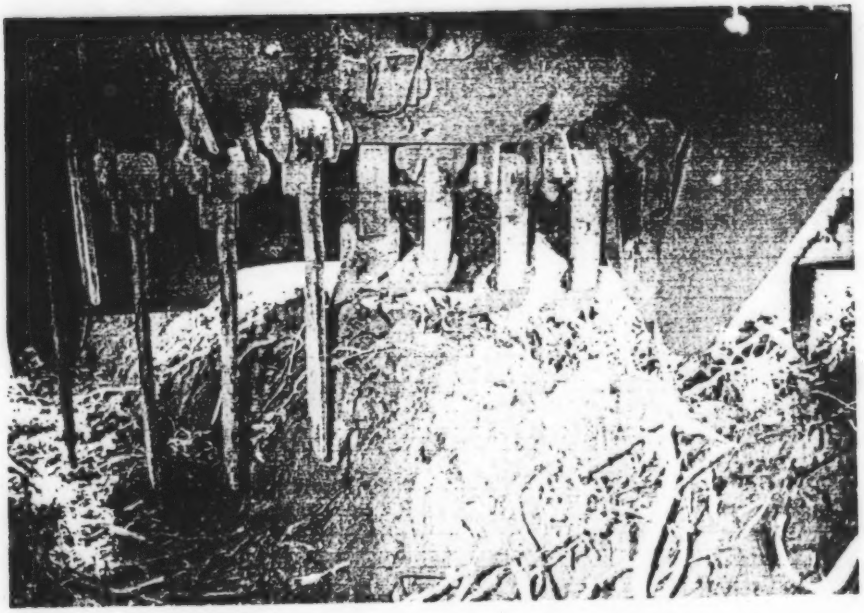


Figure 2. AMAC Flails.

Figure 3. Alloway.

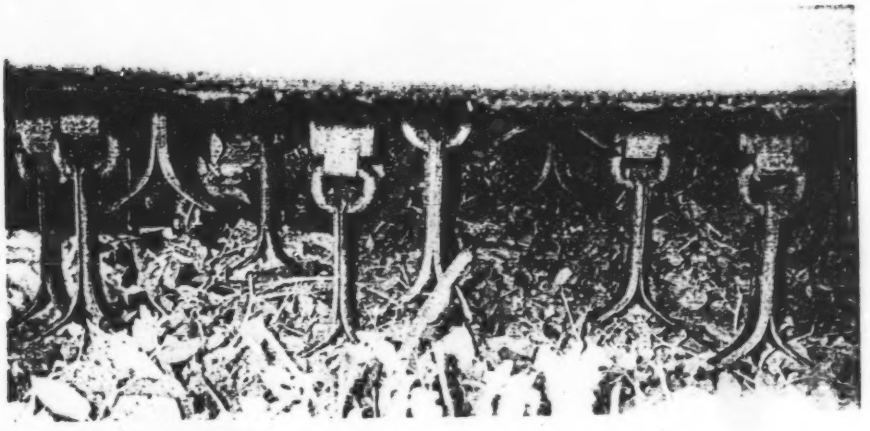


Figure 4. Alloway Flails.

The plots were 30 m (98 ft) long by four rows wide and there were four plots for each machine. There were two, 30 m (98 ft) plots for the 3.2 km/h (2 mph) test; one, 30 m (98 ft) plot for the 6.4 km/h (4 mph) test; and another 30 m (98 ft) plot for the 9.6 km/h (6 mph) test. Data acquisition equipment was attached to measure draft and PTO power (**Figure 5**).

Figure 5. Data Acquisition Equipment.

Financial analysis was conducted using a combination of data from the tests, as well as, the formulas and common machinery cost data from the SAF "Custom and Rental Rate Guide 2000/2001".

2.4 Results and Discussion

2.4.1 Engineering Assessment

Rate of Work: The rate of work is a function of the cutting width and travel speed. The AMAC working width was four rows or 3.6 m (12 ft). The Alloway machines were six rows wide or 5.5 m (18 ft), but the growers only used them to cut four rows at a time because the majority of local potato seeding and harvesting machines are based on four rows. (They had apparently been purchased as used implements from an area where six rows is the common implement width.) For the test, it was decided to also use the Alloway as a four-row machine to match local practice.

Both machines were run at 3.2, 6.4, and 9.6 km/h (2, 4, and 6 mph) and the work rate for those speeds are shown in the following (**Figure 6**). Work rates are based on travel speed, width, and the SAF standard 82.5% field efficiency to account for time spent turning corners and other events that would delay operation.

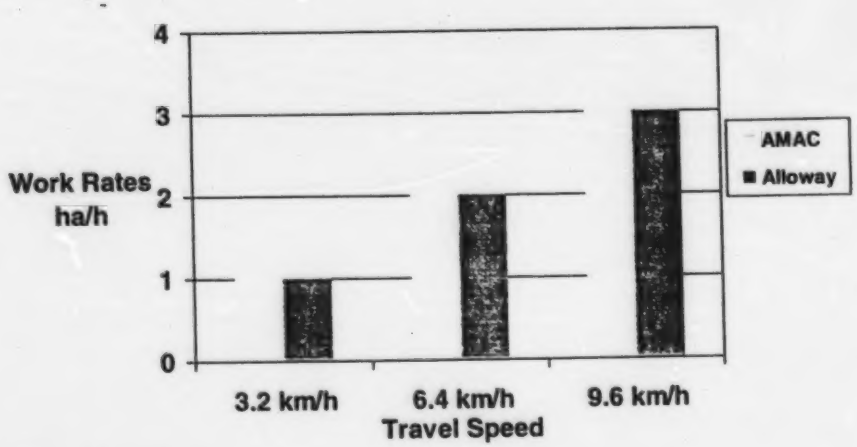


Figure 6. Work Rates.

Quality of Work: Based on discussions with Dr. Wahab and some growers, it was determined that a desirable result of the flailing operation was having the majority of the vine cut from the stalks and directed into the furrow between the rows. Approximately 15 cm (6 in) of the stalk should remain in place sticking out from the ground. This was seen as the compromise of enough plant to absorb the Reglone, kill the plant and stop growth without excess foliage surviving to require additional Reglone application or interfere with subsequent harvest.

Photographs of the potato plant after various flailing operations are shown in **Figures 7** to **16**. Based on the above criteria, preliminary results suggested the AMAC was visually more effective at cutting off the vines. Furthermore, it was more effective at directing the cut vines into the furrow away from the hill to allow the remaining standing stalks to be fully exposed for subsequent chemical operations.

Figure 7. Potato Tops Prior to Flail.

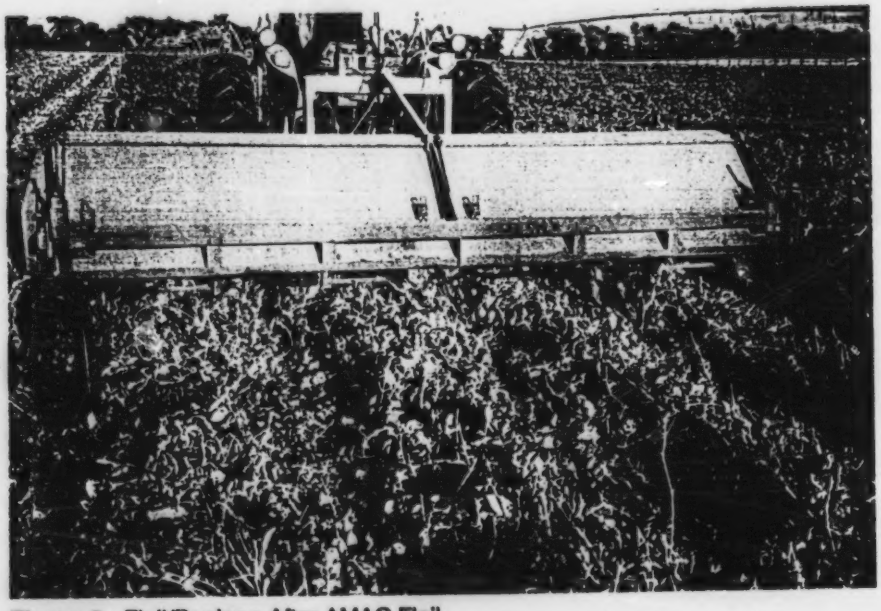


Figure 8. Flail/Reglone After AMAC Flail.

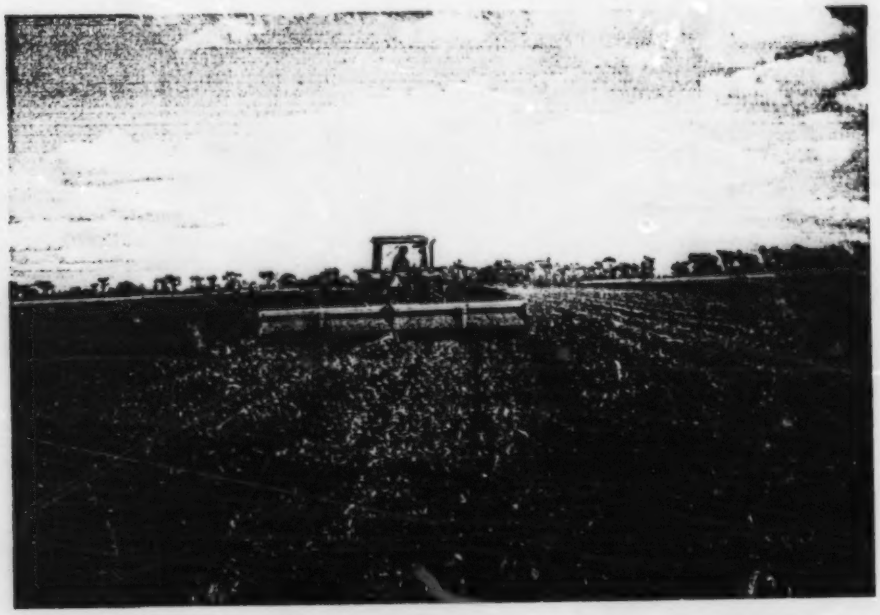


Figure 9. Flail/Reglone After Alloway Flail.

Figure 10. After Reglone Prior to Flail.

Figure 11. Reglone/Flail/Reglone After AMAC Flail.

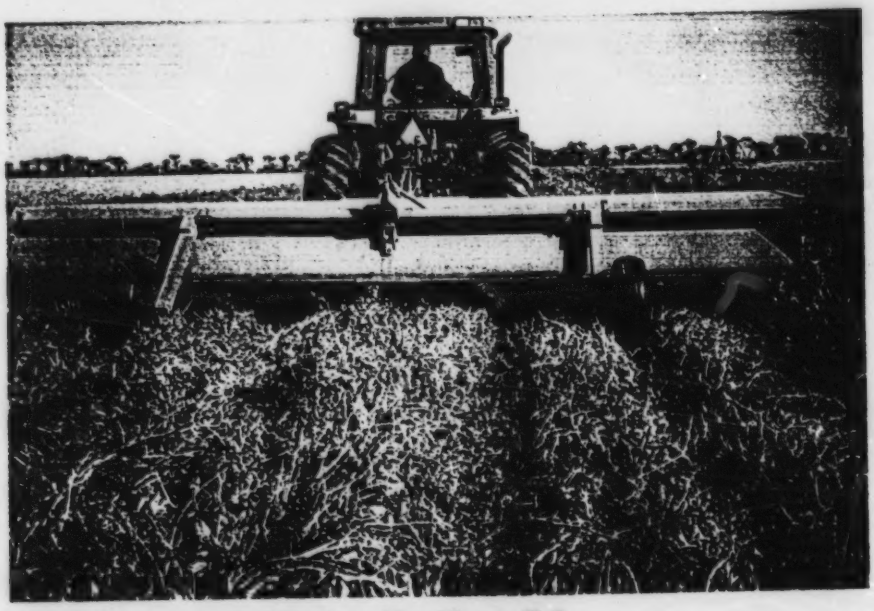


Figure 12. Reglone/Flail/Reglone After Alloway Flail.

Figure 13. Reglone/Reglone/Flail – Prior to Flail.

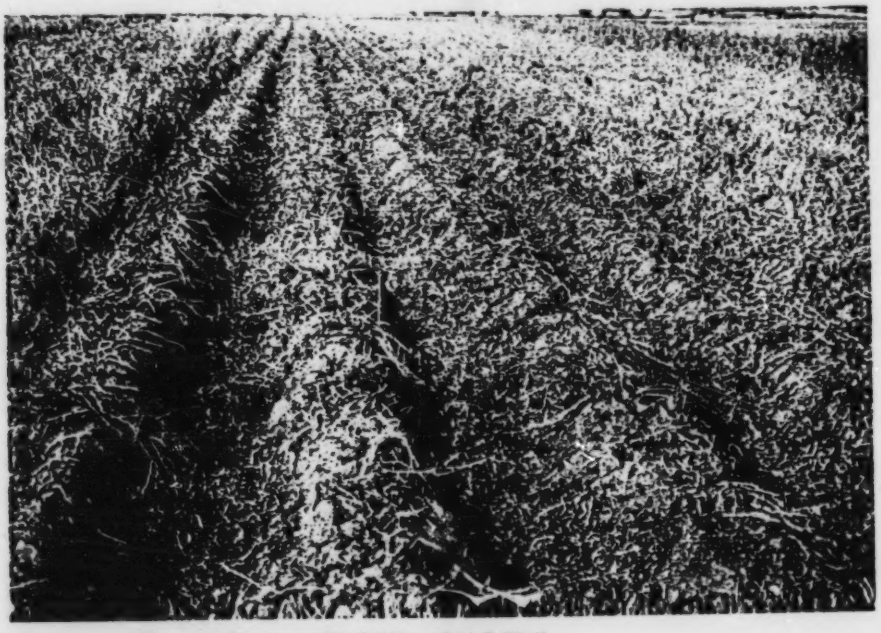


Figure 14. Reglone/Reglone/Flail After AMAC Flail.

Figure 15. Reglone/Reglone/Flail After Alloway Flail.

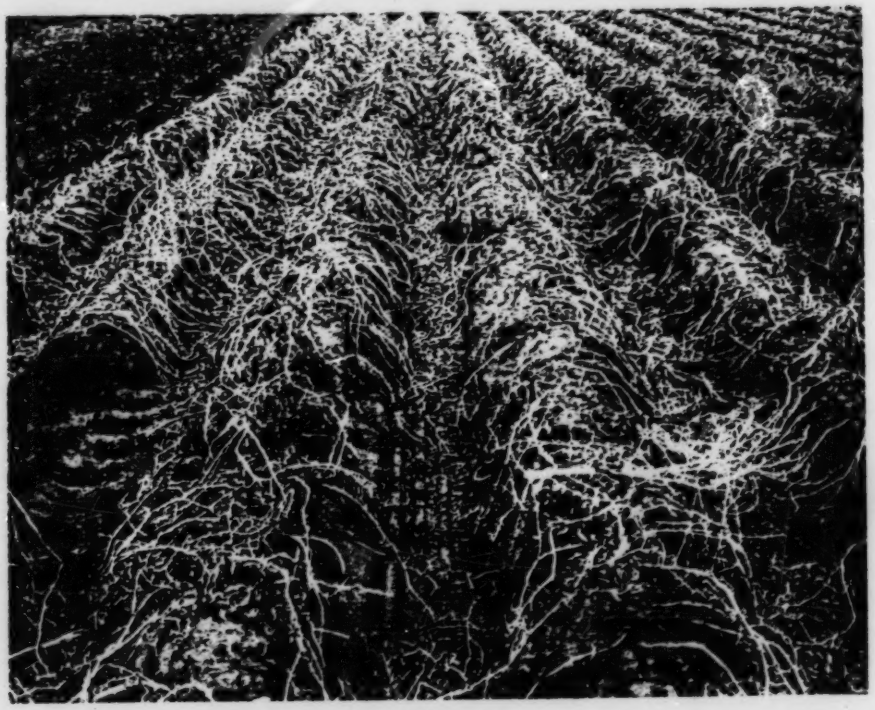


Figure 16. Reglone/Reglone – Prior to Harvest.

At 3.2 km/h (2 mph) both machines operated well in all treatments. At 6.4 km/h (4 mph) the operators were able to control their machines but some small notable differences were observed in the quality of cut. At 9.6 km/h (6 mph) the operators had concerns about properly controlling their machines, especially for the FR Treatments where the furrows were difficult to see. Quality of cut at this speed was reduced very noticeably.

In addition to visual differences in quality of cut between the machines, there were also notable differences between the years. **Figure 17** shows the crop after flailing with the AMAC in 2000 which is a much more thorough job than was done by the same machine in 2001 (**Figure 7**). Thus the crop and associated conditions can have as much effect as differences between different machines.

Figure 17. Treatment Flail/Reglone After AMAC Flail in 2000.

To determine whether these differences in visual observations were large enough to result in a significant difference in potato quality or yield, the agronomic results in a subsequent section need to be reviewed.

Another consideration under Quality of Work was how the treatment affected the subsequent harvesting operation. This factor had not been identified before or during the project but was raised by several growers at the 2001 SSPGA Annual meeting after the project was over. To address this, PAMI went back to the growers with additional survey questions. They were asked to identify their top-kill strategy and then comment whether the harvest operations encountered "No Problems, Minor Problems, or Major Problems" with vine tangling, etc. Of those using a flail in top-kill operation, 57% reported "No Problem", while 13% reported "Major Problems". Of those that only used chemical treatment, 33% reported "No Problem" and 44% reported "Major Problems". Thus, it would appear that mechanical flailing also has benefits for the subsequent harvest operation.

Power Requirements: Power take-off and draft power were measured for the treatments (**Figures 18** to **20**). Total power requirements for the AMAC ranged between 15 to 22 kW (20 to 30 hp) for all treatments. Total power requirements for the Alloway ranged from 26 to 82 kW (35 to 110 hp). Part of the reason for the extra Alloway power was the extra 50% width. A theoretical graph is shown for the FR treatment (**Figure 21**) where the Alloway power is reduced to simulate its power requirement if it were only a 4 row machine. However, in this treatment, its power requirement is still more than double the AMAC. These differences must be due to the differences in the design. For both machines, power requirement increased with speed. For the Alloway, higher power requirements were required in the treatment with the greener vines while the AMAC was less affected by these differences.

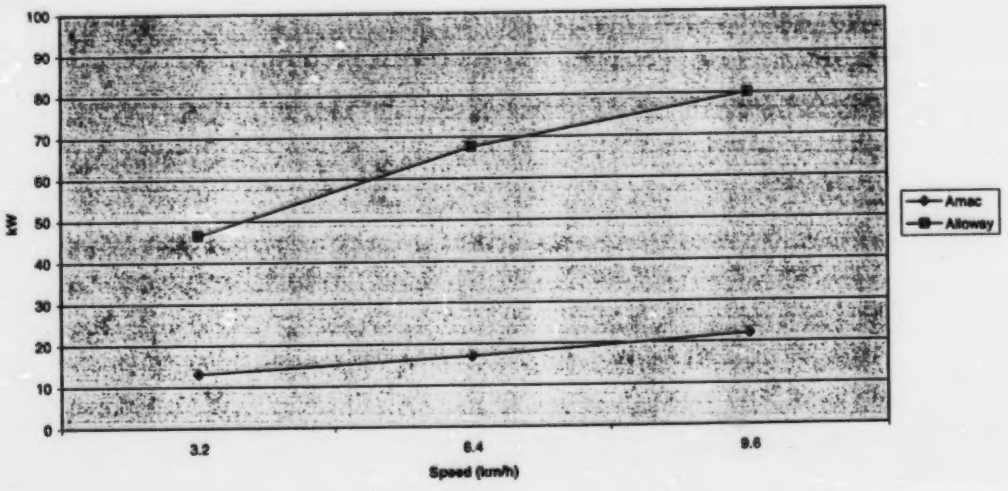


Figure 18. FR Treatment.

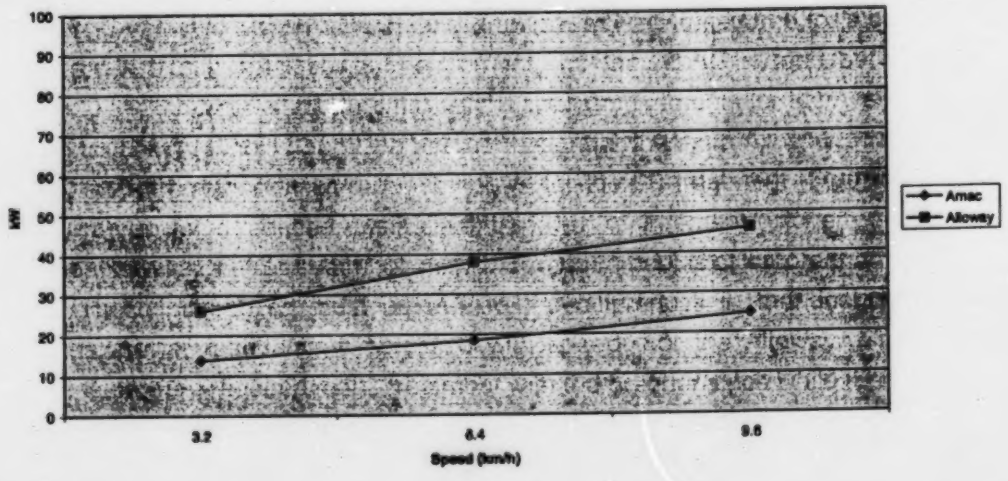


Figure 19. RFR Treatment.

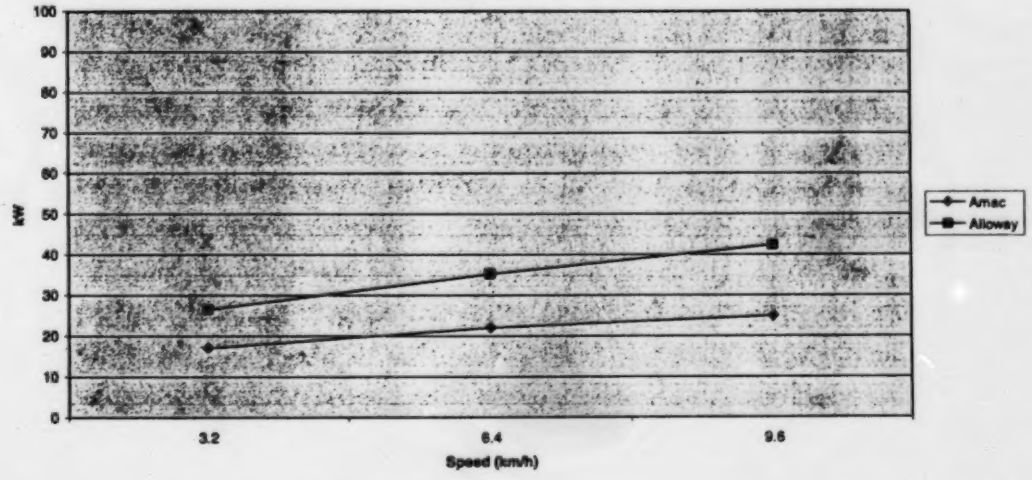


Figure 20. RRF Treatment.

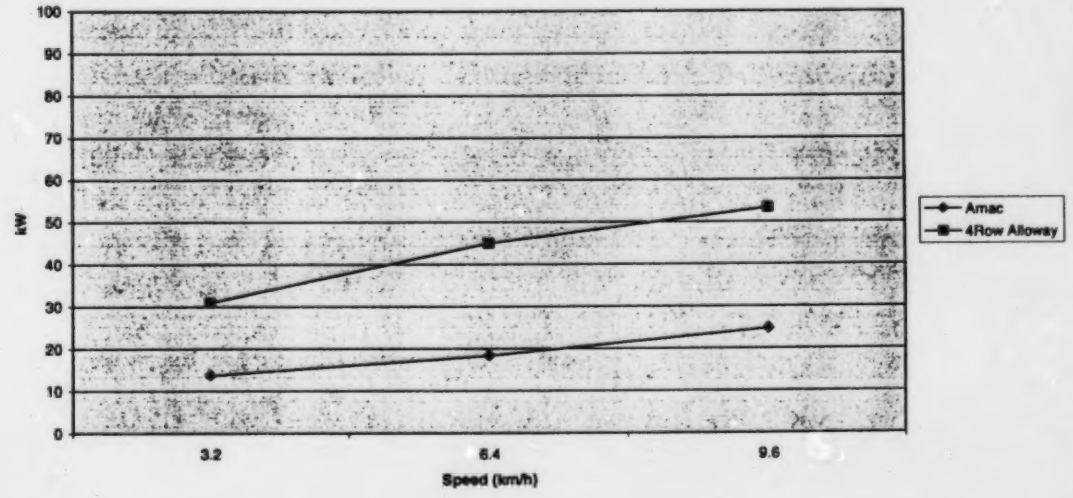


Figure 21. FR Treatment (4 Row Alloway).

A further power related requirement was due to the machine weights. The manufacturer specified weight of the AMAC was about 770 kg (1,700 lb). However, the Alloway had specifications of 300 kg/m (200 lb/ft), which would represent 1,640 kg (3,600 lb) for the unit tested. Also in the 2000 test, it had the extra attachments of rollers that further increased its weight. Because of the respective weights of these three-point hitch units, the AMAC was comfortably handled by a 52 kW (70 hp) tractor but the Alloway required a tractor of about 93 kW (125 hp) and benefited from the extra forward weight of a Front Wheel Assist tractor to counter balance the heavy implement. These two different tractor requirements will translate into significantly different tractor costs (capital and operating) between the two flails. However, as mentioned before, a four row Alloway would weigh about 30% less and require a smaller tractor.

These tractor requirements and associated costs would not likely be significantly affected by the treatment chosen because it is the flail weight, not power requirement, that primarily determined the required tractor size.

Durability: In setting up the project, the grower advisors felt that durability would be important to assess.

No breakdowns occurred on the AMAC during the test and no breakdowns were reported by the owner in this season.

No breakdown occurred on the Alloway during the test but one test had to be delayed because a gearbox failed while operating in the owners' field. Obtaining a replacement gearbox seemed to be a time consuming task.

PAMI also surveyed 15 flail owners in Saskatchewan (**Appendix III**). Other than one failed gearbox on a machine, most breakdowns were minor. The growers were asked to rate their satisfaction with durability where a rating of 10 was totally satisfied and 0 was very dissatisfied. The average score was 8.5.

Operator's Manuals: The Alloway manual is over eighty pages and contained detailed information. The AMAC manual is five pages and has much more basic operating information.

Safety: Common safety devices such as shields on rotating power shafts were on both machines and no hazards were apparent during operation.

2.4.2 Agronomic Results

Total seed grade yields and yields of Grade A and Grade B tubers, as influenced by the various vine kill treatments in both years for the two tested flails, are presented in **Table 3**.

Some differences were observed. In 2000, there were higher Grade B yields than Grade A. Conversely in 2001, there were higher Grade A yield than Grade B. Also in 2000, the Reglone/Reglone treatment had a lower yield than the other treatment but in 2001, this was not observed. Overall there were no statistically significant differences and this is generally observed on the following **Figure 22** when the average of the two years is shown.

Table 3. Seed Grade Tuber Yields.

Treatment	Tuber Yield (t/ha)											
	2000						2001					
	Alloway			AMAC			Alloway			AMAC		
	Grade A	Grade B	Total	Grade A	Grade B	Total	Grade A	Grade B	Total	Grade A	Grade B	Total
Treatment FR	9.1	14.9	24	8.1	14.7	22.8	17.9	9.9	27.8	17.9	9.9	27.8
Treatment RFR	10.6	11.9	22.5	9.6	13.9	23.5	21.6	12.1	33.7	18.6	12.1	31.7
Treatment RRF	8.3	12.8	21.1	7.2	12.3	19.5	18.9	9.9	28.8	19.8	10.5	30.3
Treatment RR	7.2	9.9	17.1	7.7	12.2	19.9	19.1	11.5	30.6	21.7	10.8	32.5
Significance	ns	**	**	ns	**	ns	ns	ns	ns	ns	ns	ns
LSD (5.0%)	1.9	-	2.6	-	1.3	-	-	-	-	-	-	-
C.V. (%)	20.1	12.1	11	24.6	9.4	13.3	13.1	13.5	10	16	14.4	11.8

ns = Not Significant, ** = Significance @ P < 0.01 Level of Probability, LSD = @ 5% Level of Significance, CV = Coefficient of Variation.

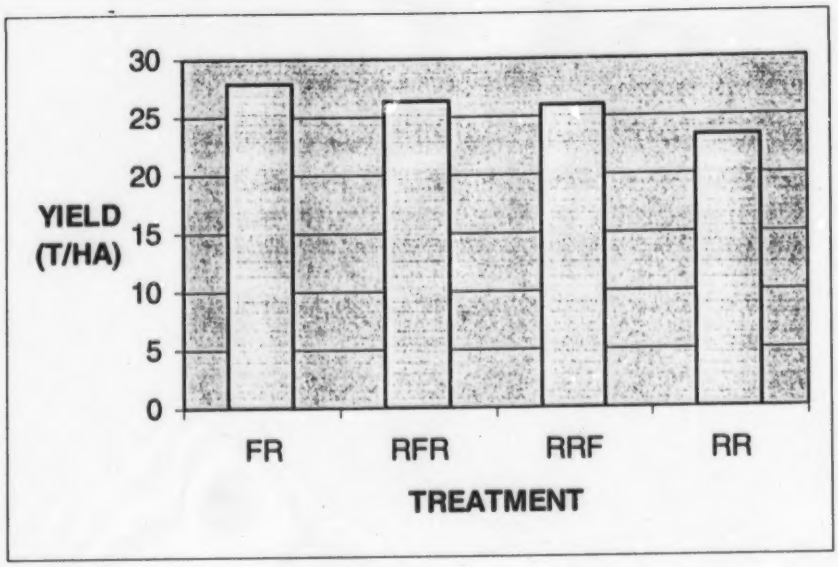


Figure 22. Treatments and Yields.

Average tuber weight as influenced by the various vine kill methods in both years for the two tested flails are presented in **Table 4.**

Table 4. Average Tuber Weight.

Treatment	Average tuber weight (g)							
	2000				2001			
	ALLOWAY		AMAC		ALLOWAY		AMAC	
	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
Treatment FR	123	63	124	62	168	65	168	65
Treatment RFR	131	65	124	63	164	60	161	62
Treatment RRF	128	65	122	62	164	59	166	64
Treatment RR	141	63	119	63	164	61	154	62
Significance	ns	ns	ns	ns	ns	ns	ns	ns
LSD (5.0%)	-	-	-	-	-	-	-	-
C.V. (%)	6.7	7.3	5.3	3.2	6.3	10.9	7.8	11.6

ns = Not Significant, CV = Coefficient of Variation.

Flailing and desiccation treatments did not significantly affect average tuber size in either year.

Average tuber specific gravity as influenced by the various vine kill treatments in both years for the two tested flails are presented in **Table 5.**

Table 5. Tuber Specific Gravity.

Treatment	Tuber specific gravity			
	2000		2001	
	Alloway	AMAC	Alloway	AMAC
Treatment FR	1.0660	1.0630	1.0775	1.0775
Treatment RFR	1.0695	1.0695	1.0753	1.0775
Treatment RRF	1.0660	1.0665	1.0758	1.0775
Treatment RR	1.0660	1.0665	1.0775	1.0777
Significance	ns	**	ns	ns
LSD (5.0%)	-	0.0026	-	-
C.V. (%)	0.19	0.23	0.27	0.33

ns = Not Significant, ** = Significance @ P < 0.01 Level of Probability, LSD = @ 5% Level of Significance, CV = Coefficient of Variation.

The RFR Treatment of 2000-AMAC had significantly higher tuber specific gravity. However, this trend did not show in 2001. Generally, all treatments produced similar tuber specific gravity.

Although not measured in detail, there were general observations made on the effects of treatments on skin set, bruising, stem end browning, storage loss, and disease incidence. Although some stem end browning was recorded in 2001, it was very slight and had not been observed in 2000. Generally, though there were no differences in any of the above parameters between any of the treatments.

Notable visual differences seemed apparent in the quality of cut between the two machines. To determine if this translated into a field difference, the average of all treatments using the AMAC was compared to the average of all treatments using the Alloway (**Figure 23**).

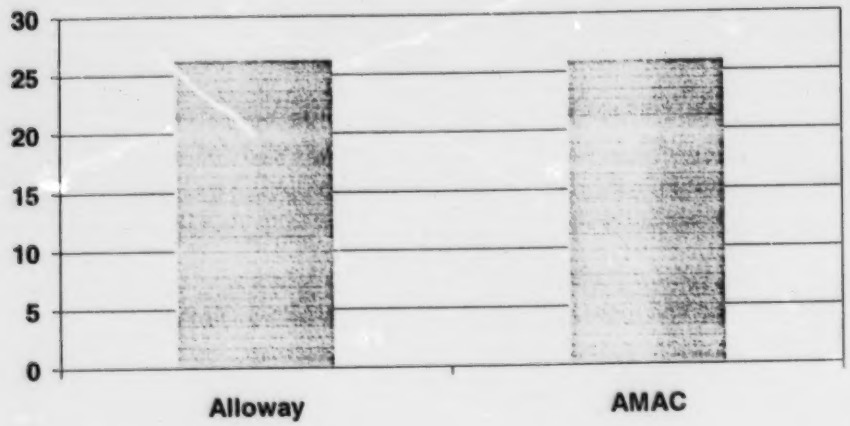


Figure 23. Flailing and Yield (t/ha).

This graph suggests that the visual differences did not translate into any yield difference between the machines.

2.4.3 Financial Results

Using project data and SAF machinery cost formulas, the respective costs of operating the machines and the respective cost of each treatment were determined.

The respective machine costs are based on the following data (**Table 6**).

Table 6. Cost Calculation Data.

Machine	Alloway	AMAC
Capital Cost ($)	15,750	15,750
Lifetime (hr)	3,000	3,000
Machine Width (m)	3.7	3.7
Operating Speed (km/h)	4.8	4.8
Tractor Size (kW)	67	45

Respective machine costs are shown in **Figure 24**.

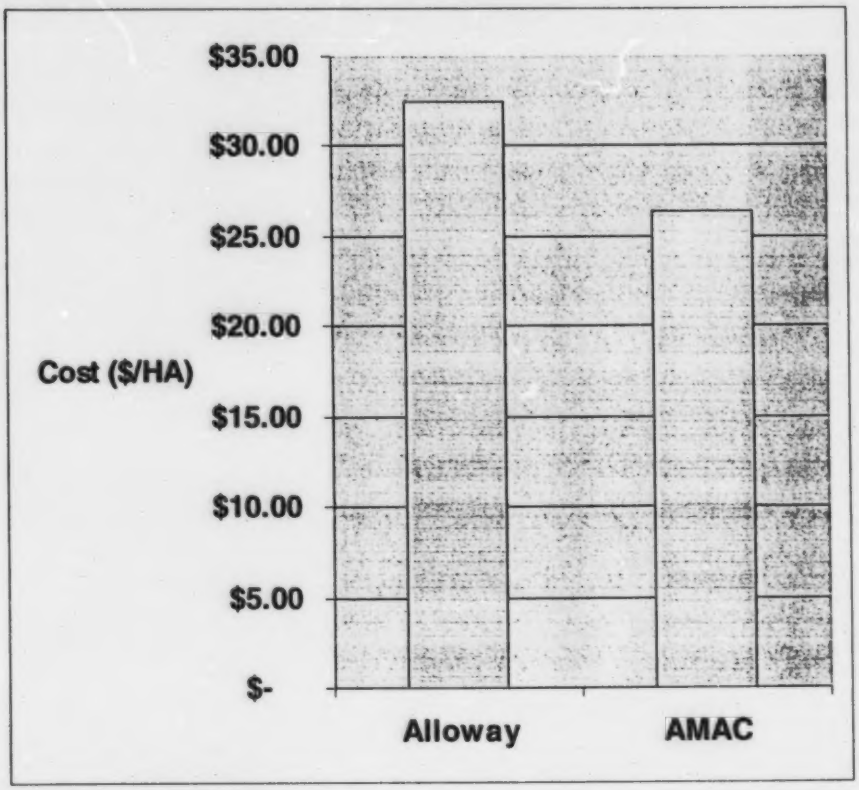


Figure 24. Machine Costs.

The main difference between the respective operating costs is the larger tractor requirement for Alloway.

The respective treatment costs are based on the follow data **(Table 7)**.

Table 7. Treatment Calculation Data.

Reglone	$19.10/L
Aerial Spraying	$14.70/ha
Flailing	$29.64/ha

Respective treatment costs are shown in **Figure 25**.

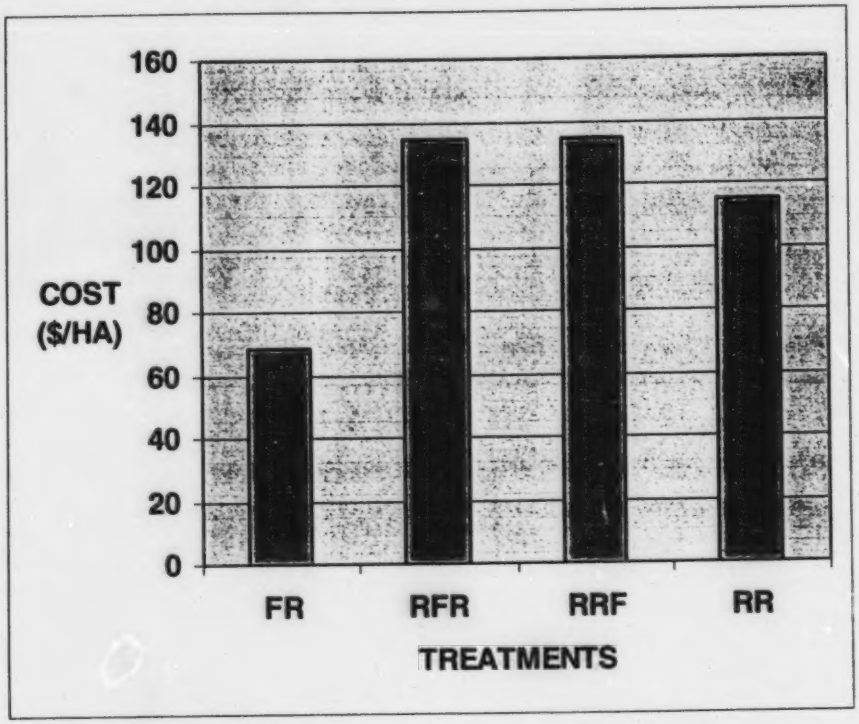


Figure 25. Treatment Costs.

The FR treatment is the least cost. The RR treatment is second while the RRF and RFR are the most costly.

3. Conclusions and Recommendations

Engineering comparisons of the Alloway and AMAC machine suggested there were no differences between the work rate of the two machines when used to cut four rows on a pass. The AMAC appeared to do a more desirable visible job of cutting the vines and it had lower power requirements.

Agronomic comparisons suggested little or no difference between any of the treatments. Also the visible differences observed between the two machines in quality of vine cut did not appear to translate into any difference in yield.

Financial comparisons showed that the Alloway had a slightly higher operating cost, primarily because it required a larger tractor. Also the Flail/Reglone treatment was the least costly of the four treatments.

Thus, since the Flail/Reglone treatment was the least cost operation and showed no reduction in yield or other agronomic performance data, it has merit as a method to Top-Kill Seed Potatoes.

The Growers have seen considerable merit in this multi-discipline project and have expressed interest in a similar comparison of Potato Harvester equipment. PAMI and CSIDC will pursue such a project.

6. Project Developed Materials

A power point presentation was developed for this project and presented at the December 2001 SSPGA annual meeting. A CD of the presentation has been sent to ADF with this report.

7. Project Photos

Project photos are included in the Technical Section of this report as well as on the Power Point CD.

8. Acknowledgements

The contribution from SAF ADF was acknowledged at both the 2000 and 2001 SSPGA meetings. It is also listed on the Power Point CD and at the start of this report.

APPENDIX I

Appendix I

Northern Vigor™

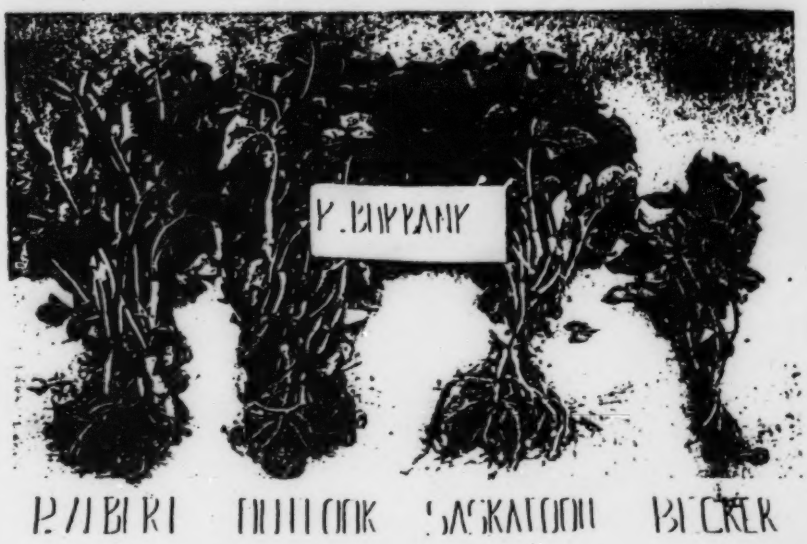
Saskatchewan Irrigation Development Centre

Outlook, Saskatchewan
Ph. (306) 867-5400

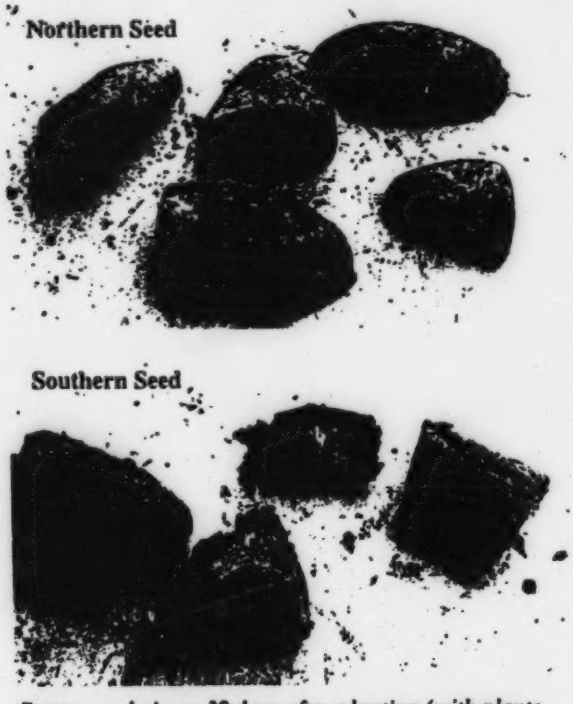
Northern Vigor™ in Seed Potato

January, 1998

Potato growers from the southern U.S.A. and some parts of Europe consider seed potatoes grown in northern latitudes to produce more vigorous and higher yielding crops than seed from southern latitudes. This superiority was presumed to be due to reduced levels of seed borne disease and/or some inherent physiological characteristics of the seed tuber itself. However, the exact reason(s) for this Northern Vigor™ is not known. In 1986, a research project was started at the Department of Horticulture Science, University of Saskatchewan to determine the basis for the Northern Vigor™ phenomenon.



Northern Vigor™ in potato. Plants grown from Saskatchewan-produced seed are more vigorous and are higher yielding than those grown using a southern seed source.



Potato seed pieces 30 days after planting (with plants removed). Northern stock remains sound with little decay.

Yield Evaluation

A preliminary study using certified seed of Norland and of Russet Burbank potatoes from Minnesota, Nebraska and Saskatchewan (Outlook and Prince Albert) were evaluated in field plots at Saskatoon. Results indicated that the Norland seed from Saskatchewan outyielded the southern sources by an average of 19%. For Russet Burbank the increase was 55%. The certified seed used was considered to be free of major seed-borne diseases, therefore the superior performance of the northern seed tubers could have been caused by physiological differences in the seed.

More detailed studies were conducted from 1987 to 1992. Genetically uniform seed-tubers, obtained by increasing a single original seed stock at various locations, were used. All seed was stored under the same conditions until planting.

Replicated field trials were carried out at several locations to compare crop growth and tuber yield of seed from the various Saskatchewan (LaRonge, Prince Albert, Saskatoon, and Outlook), and southern (Colorado, Minnesota, and Wisconsin) sites. Yield tests were conducted in Saskatchewan, Minnesota, and Colorado.

Canada

Saskatchewan

The yield advantage obtained by using Northern seed was consistent for all sites in all seven years. The Saskatchewan grown Norland outyielded the southern seed sources by 5 - 27%. For Russet Burbank the yield advantages were as great as 133%.

Canopy development of Russet Burbank grown from northern seed (top) compared to southern seed (bottom) 64 days after planting.

Physiological Basis for Northern Vigor™

Tests indicated that the yield differences were not caused by seed-borne disease. The superiority of seed-potatoes produced in northern latitudes appears to be due to some physiological change(s) in the seed-tuber.

Potato crops grown from northern seed produce more vigorous plants having delayed senescence (i.e. a longer period of active growth), and produce larger tubers with less variation between hills. This results in even crop development, higher yield, and superior grades.

The relative vigor and yield potential of the various sources was likely influenced by temperature during the seed production season. Locations with strong diurnal temperature differences (warm days and cool nights) produced more vigorous seed than sites with lower day to night temperature change.

An experiment using single-leaf cuttings showed that low yielding southern seed sources contained higher levels of a "tuberizing stimulus" than higher yielding northern seed lots. Higher levels of the tuberizing stimulus favored early tuber set and rapid tuber bulking at the expense of shoot growth. This reduces tuber yield at maturity, especially in the late maturing Russet Burbank variety.

Higher yielding seed lots originating from the northern sources had less moisture loss and decay than southern sources over the winter storage period. Northern seed was also found to be more tolerant of planting in cold soil conditions than was southern seed.

The vigor of the Saskatchewan potato seed carried over for at least one additional year. Saskatchewan seed was planted in Minnesota in 1988. This crop was kept and planted in Minnesota in 1989. The vigor and yield potential of this seed stock was lower than that of seed directly from Saskatchewan, but it remained superior to the southern seed.

Conversely, it was also possible to increase the yield potential of Minnesota seed lots by growing them for a season in Saskatchewan. This brought the yield potential of seed originally from Minnesota to that of seed grown exclusively in Saskatchewan. Vigor of seed lots can be improved by growing them in a northern climate for one season.

Research findings and grower experience indicate that greatest benefits for using northern seed can be obtained in climates with long growing seasons and less than ideal environments. These conditions prevail in the Pacific North Western United States, and in Mexico, making them potential markets for western Canadian seed potatoes.

For further information contact the Saskatchewan Irrigation Development Centre, or the Dept. of Horticulture at the University of Saskatchewan.

Northern Vigor is a trademark of the Saskatchewan Seed Potato Growers Association.

APPENDIX II

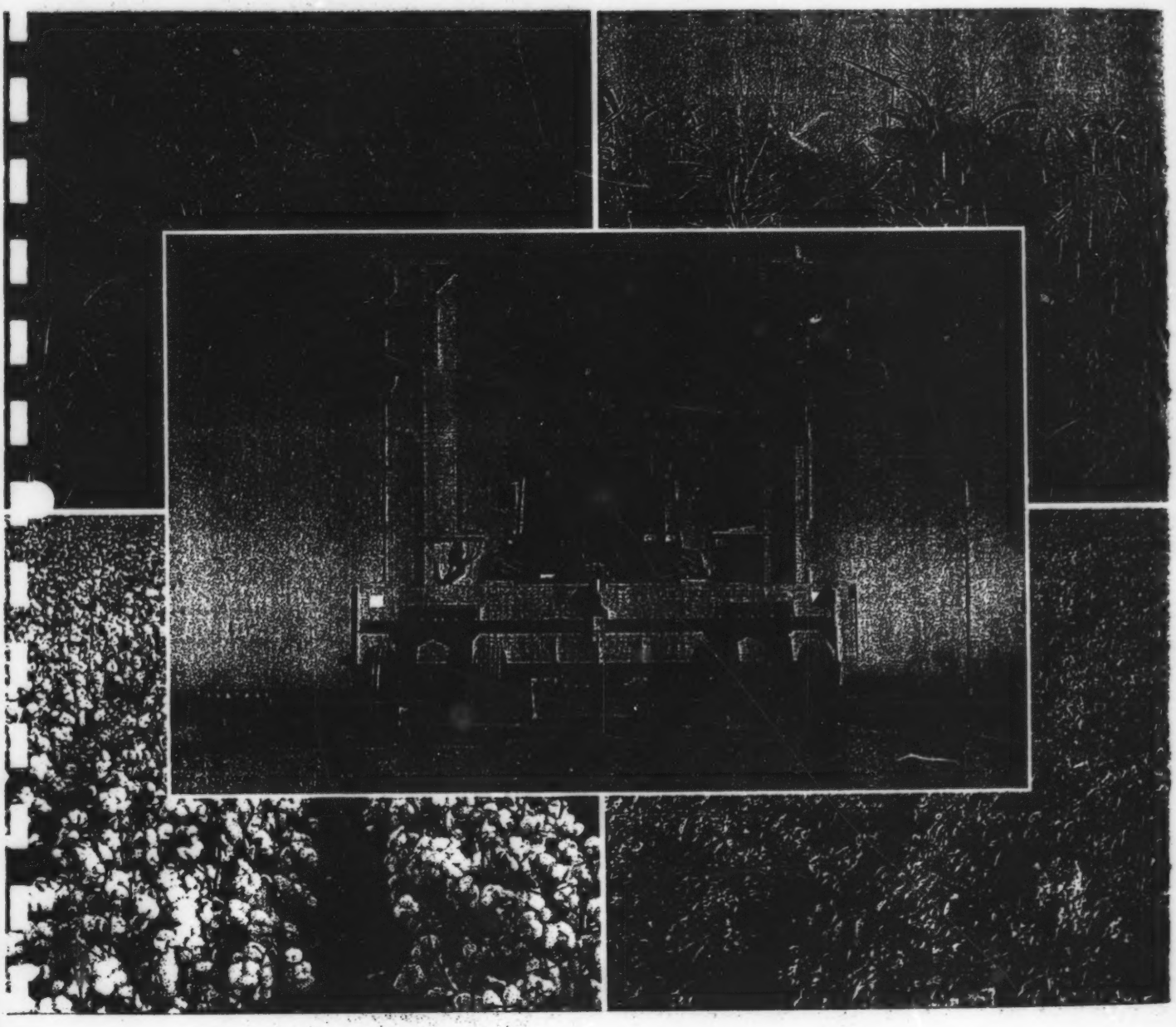
Appendix II

Flail Shredder Product Literature

ALLOWAY

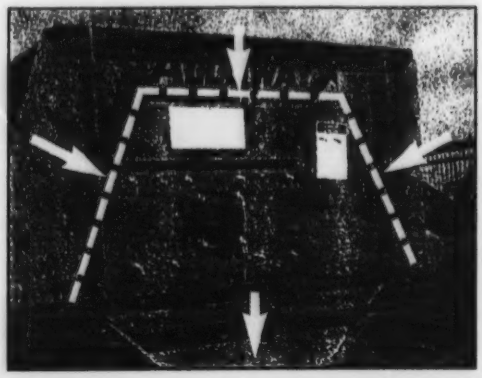
Shredders

Sept. 18/00



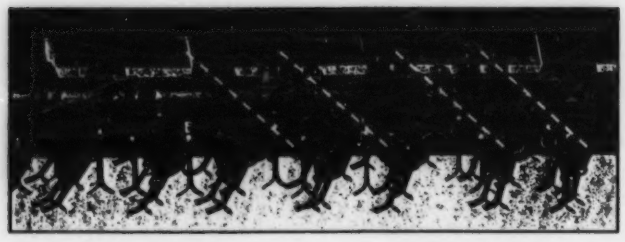
Corn	Sugarbeets
Cotton	Specialty Crops
Small Grains	Potatoes
Rice	Milo

The Woods Advantage
Get It With The Alloway Flail Shredder



Tri-Lateral Hood Design - 3/16"(4.8mm) Thick

Creates QUADRUPLE shredding action (see arrows)! The first cut occurs at the cutting level; it shreds a second time at the front panel; again at the top of the unit; and a fourth time at the back. Design also provides structural reinforcement.



Spiral Mounted Flails

Eliminates "pulsing" for smoother, more efficient operation. Also reduces mechanical stress and wear on the shredder drive system and tractor.

Dynamically Balanced Flail Mounting Tube

7" (178mm) and 7 1/4" (184mm) flail tube is precision balanced for smooth operation.

Front Rubber Flaps

New, durable molded rubber flaps (5/8"(16mm) thick by 6"(152mm) wide) keep debris and other materials beneath the shredder and away from the tractor and operator. More protection for added safety.

Adjustable Rear Gauge Wheels

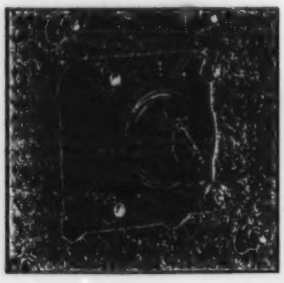
Maintains accurate height of shredder and allows precise ground clearance. Easy to adjust to match row spacing.

"Superior" Brand Gearboxes

Built to meet strict quality control standards.

Features include:

- Split case design to eliminate adjustments and shimming. Cuts downtime.
- High strength, aluminum alloy gear case provides exceptional heat dissipating qualities, eliminates weak corners, extends box life and reduces maintenance.
- Heavy-duty gears and shafting assure longer, more dependable performance.
- Dipstick for easy oil level check.



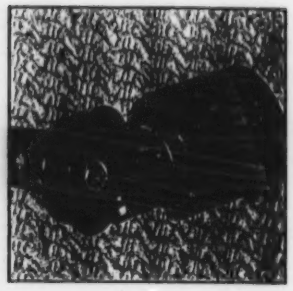
Exclusive Triple-Sealed 1 15/16" (49mm) Outboard Bearings

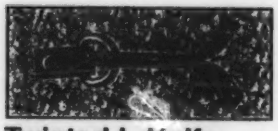
Protects bearings against dust, extending life of the bearings. Also assures smooth operation and low maintenance. Anti-rotation clip prevents bearing from turning inside cast housing.

Cup Flail Cutting Knife
Cup flails create vacuum action to lift foliage off the ground and up into the shredder. Features a hardened steel bushing for longer life. Also available with optional hardened Dura-Face edge.

L-Knife Flails
This 1/4" (6.4mm) knife delivers 100% overlap for double cutting performance.

Protection Clutch
Single bolt, self-setting connection for simple attachment. Has both a friction clutch and overrunning clutch to protect the shredder drive system.

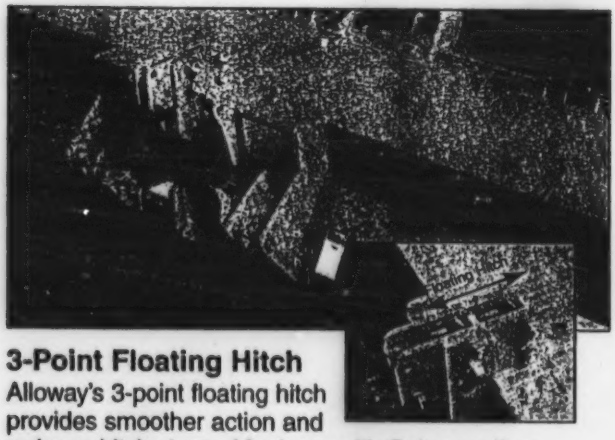




Twisted L-Knife
This heavy-duty, 5/16" (7.9mm) knife combines the vacuum action of the cup knife with a long cutting edge to provide outstanding shredding.

P.T.O. Shafts
Available in 2 yoke sizes 1 3/8" (35mm) and 1 3/4" (44.5mm).

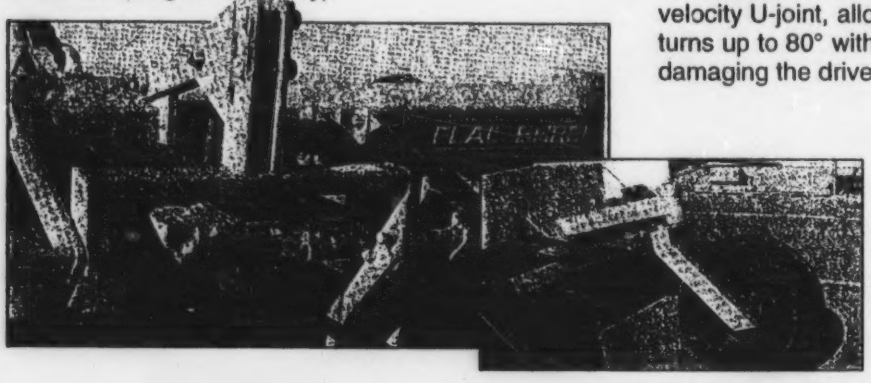
Power Requirements
Alloway shredders require a 1,000 RPM PTO system which provides flail tip speed of 128 MPH (206km/h).



3-Point Floating Hitch
Alloway's 3-point floating hitch provides smoother action and reduces hitch stress. Must use with Category II or III 3-point hitch systems with QUICK-ATTACH hitch on the tractor (on gear drive only).

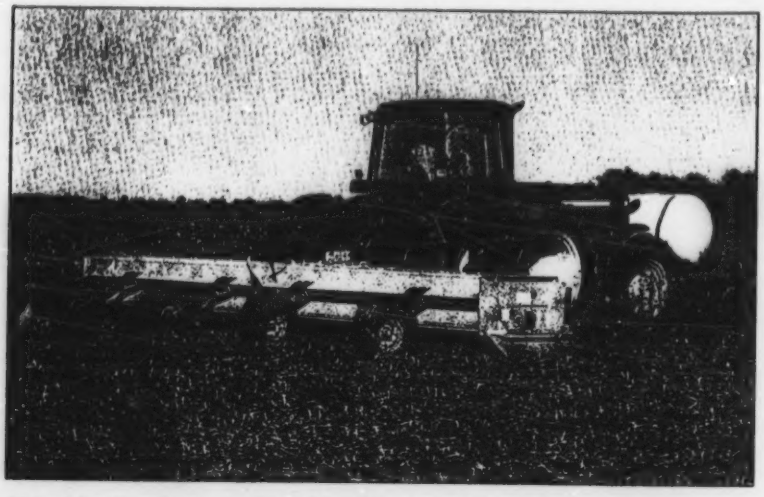
Pull-Type Hitch
Allows shredder to be trailed. Screw jack is used to level machine. The PTO shaft on the pull-type unit utilizes a constant velocity U-joint, allowing turns up to 80° without damaging the drive.

Perfect Hitch
Standard on all pull-type shredders, this heavy-duty hitch allows for easy alignment of implement to tractor. Accepts usage of different size draw pins.



2-Point Semi-Mounted Hitch with Castor Gauge Wheels
Allows partial lifting of machine for easy turning at end of field. Keeps PTO straight when turning, preventing need to shut machine down. When using 2-point hitch on end drive shredder you must use quick hitch attachment.

Center Drive Shredder



The Alloway Center Drive Shredder can field shred any crop. This unique piece of equipment can save time by allowing you to work up to 25' (7.6m) in one pass.

Features Include

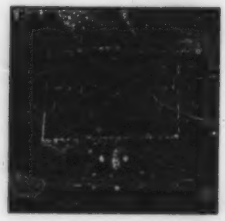
- **Center mounted gearbox drive**
- **Horsepower requirement 6-8 HP (4.5-6kW) per foot of machine width**
- **Rear gauge wheels** (2 wheels standard, 4 wheels recommended on shredders 18' (5.49m) or wider)
- **Choice of 3-point floating hitch, 2-point semi-mounted hitch or pull-type hitch**
- **Available only in 1000 RPM PTO speed**
- **Choice of L-knife or cup flails**
- **7" (178mm) diameter dynamically balanced steel flail mounting tube. 7 1/4" (184mm) tubes on 22' (6.7m), 24' (7.3m) and 25' (7.63m) models**
- **Screw jack for height adjustment**
- **Parking stands**
- **Light-duty implement hitch**

Sizes-ft. (m)	12 (3.7)	14 (4.27)	15 (4.6)	18 (5.5)	20 (6.1)	22 (6.7)	24 (7.3)	25 (7.63)
Weight-lbs.(kg) (3-point unit)	3675(1667)	3750(1701)	3995(1812)	4370(1982)	4655(2112)	5115(2320)	5326(2416)	5430(2463)
Cutting width-inches (mm)	143(3632)	167(4242)	183(4648)	215(5461)	247(6274)	271(6883)	287(7290)	303(7696)

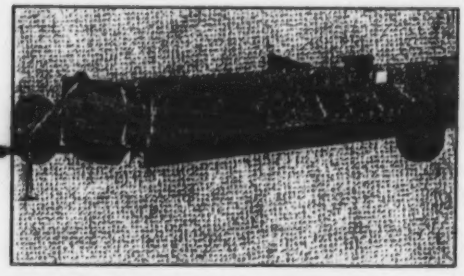
Options

- **End transport kit**
- **Hydraulic center cutter kit**
- **Baffle kit** (cup knife machines only)

Light Duty Implement Hitch
Designed for pulling light tillage implements or vehicles.



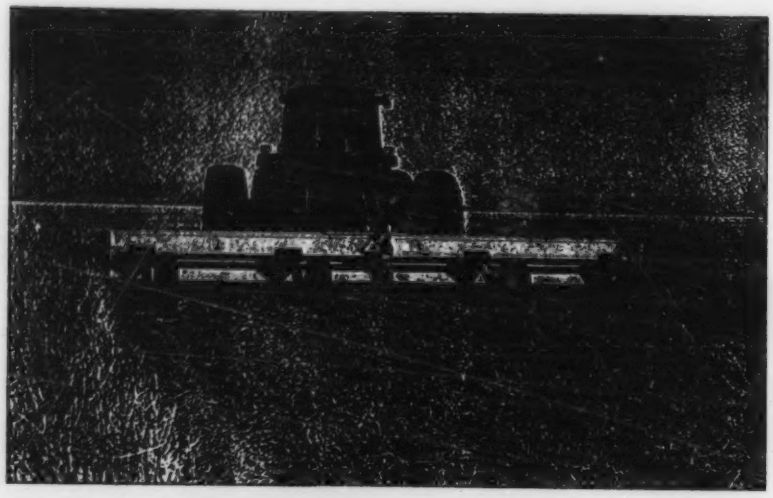
Hydraulic Center Cutter Kit (Optional)
Eliminates center strip left during normal shredding process in non-row crop applications.



End Transport Kit (Optional)
Allows easy, safe transport of unit.

Baffle Kit (Optional)
Eliminates windrowing by altering airflow, allowing trash to be discharged and spread evenly.

End Drive Shredder



The Alloway End Drive Shredder can field shred any crop. Designed for use in non-row crop applications, the unit leaves virtually no strips. Available in sizes 12' (3.66m) to 24' (7.32m).

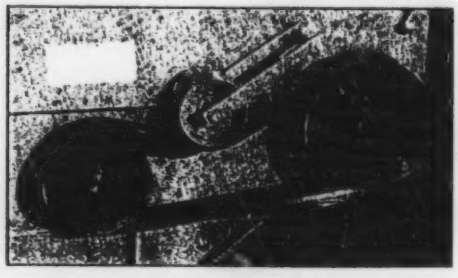
Features Include

- **12' (3.66m) to 24' (7.32m) widths available**
- **4-groove belt end drive system**
- **Belt idler pulley**
- **7" (178mm) diameter dynamically balanced steel flail mounting tube. 7 1/4" (184mm) tubes on 22' (6.7m) and 24' (7.3m) models**
- **Horsepower requirement 6-8 HP (4.5-6kW) per foot of machine width**
- **1000 RPM PTO speed** (540 RPM PTO speed available)
- **Center hanger bearing**
- **Choice of L-knife, cup or contour mounted cup flails**
- **Choice of 3-point floating hitch or pull-type hitch**
- **Light-duty implement hitch**
- **Rear gauge wheels** (2 wheels standard, 4 wheels recommended on shredders 18' (5.49m) or wider)
- **Screw jack for height adjustment**
- **Parking stands**

Sizes–ft. (m)	12 (3.7)	15 (4.6)	18 (5.5)	20 (6.1)	22 (6.7)	24 (7.3)
Weight–lbs.(kg) (3-point unit)	4115(1867)	4935(2239)	5310(2409)	5695(2583)	6215(2819)	6365(2887)
Cutting width-inches (mm)	143(3632)	183(4648)	215(5461)	247(6274)	271(6883)	287(7290)

Simple Drive System

Greater reliability with less maintenance. Incorporates one centrally mounted gearbox and two drive belts (one at each end). 12' (3.66m) shredder features a single drive belt.

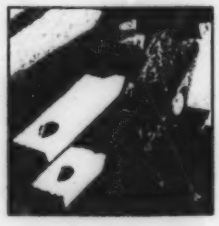


Belt Idler Tension Pulley

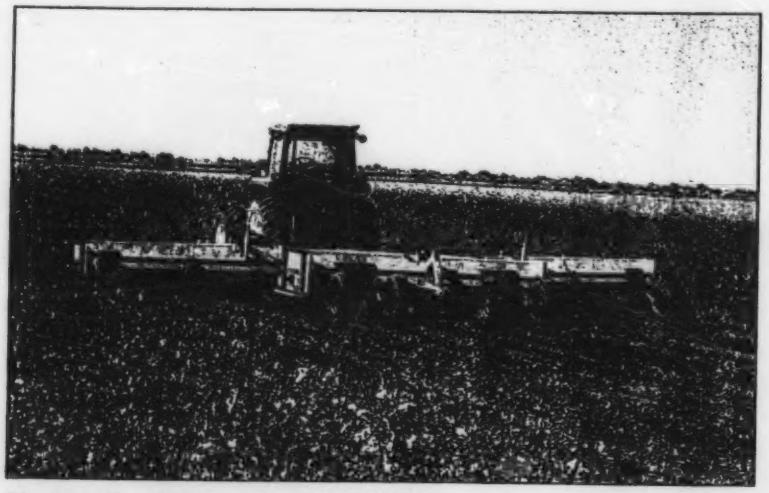
Keeps belt tight for greater efficiency and longer life. Heavy 4-groove banded drive-belt reduces slippage and assures extended wear.

Light-Duty Implement Hitch

Designed for pulling light tillage implements or vehicles.



Hydraulic Vertical Fold Shredder



Hydraulic Vertical Fold Shredder
Allows shredding without skips...up to 30' (9.15m) wide. This unit can be hydraulically folded from the tractor cab and the floating wing design allows shredding in uneven terrain.

Features Include

- Hydraulic lift system
- Floating wing design
- Hydraulic vertical fold/narrow transport width
- 4-groove belt on center section
- Heavy-duty pull-type hitch
- 6 rear gauge wheels
- Horsepower requirement 6-8 HP (4.5-6kW) per foot of machine width
- L-knife flails
- Available only in 1000 RPM PTO speed
- 7 1/4" (184mm) diameter dynamically balanced steel flail mounting tube
- Heavy-duty parking jacks
- Drive system incorporates two gearboxes and one belt

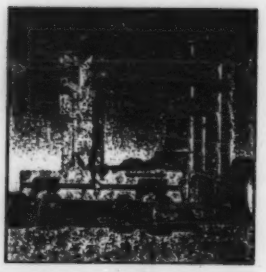
Sizes–ft. (m)	24 (7.3)	27 (8.2)	30 (9.2)
Weight–lbs.(kg) (Pull-type unit)	9790(2636)	10,490(4752)	10,825(4904)
Height–ft.(m) (Pull-type unit)	10.5 (3.2)	12 (3.7)	13.5 (4.1)
Cutting width-inches (mm)	290(7366)	322(8179)	362(9195)

Options & Accessories

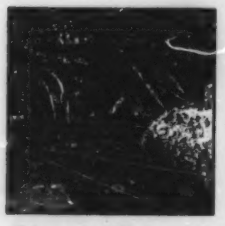
- Heavy-duty implement hitch
- Rear hydraulic valve package

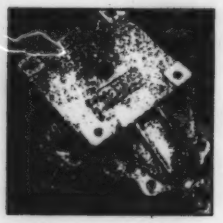
Support Wheel
Shock absorbing support wheel helps stabilize floating wings (standard on 30' unit).

Hydraulic Vertical Fold System
Has narrow transport width. System folds to a width of just 13' (4m).

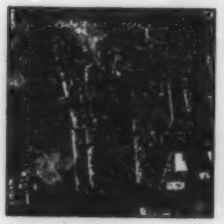


Floating Wing Design
Each wing can tilt up or down 15° from the unit's horizontal position. This feature allows for operation on uneven terrain.





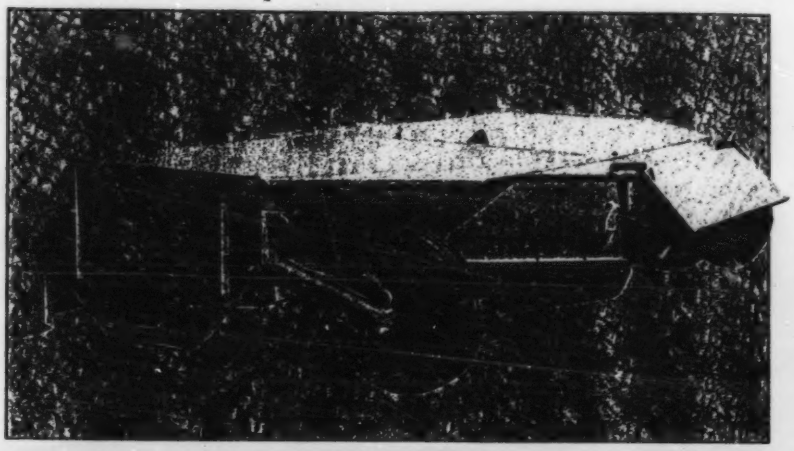
Simple Drive System
Incorporates two centrally mounted gearbox drives and one belt. System has fewer components reducing service time and lowering maintenance costs.



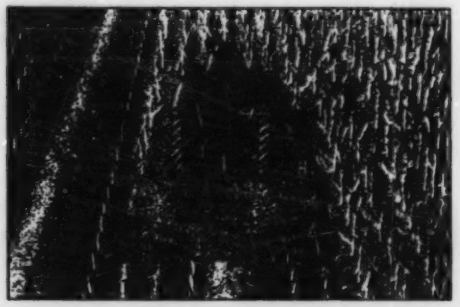
Hydraulic Lift System
Raises unit hydraulically with rephasing cylinders and single depth control stop.

Belt Idler Tension Pulley
Keeps belt tight for greater efficiency and longer life. Heavy 4-groove banded drive-belt reduces slippage and assures extended wear.

Windrow Shredder



The Alloway Windrow Shredder chops and windrows cornstalks in one pass, making a 5' (1.5m) wide windrow that's easy to bale. Turn your cornstalk residue into valuable livestock feed or bedding. System can also be converted into a standard shredder.

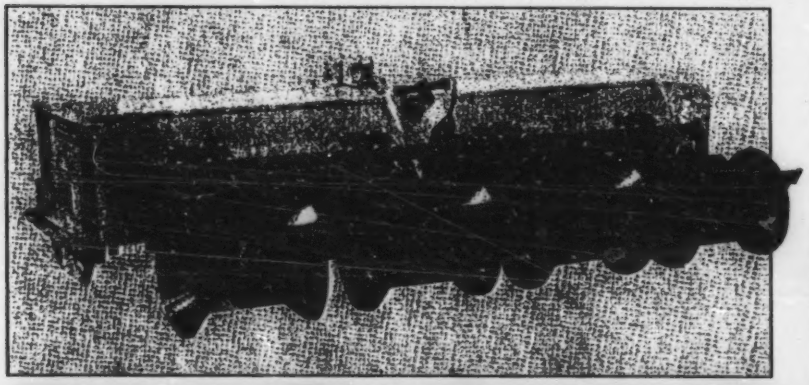


Features Include

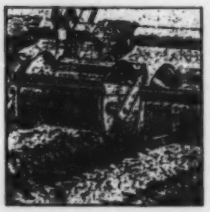
- 15' width
- Center mounted gearbox drive
- Horsepower requirement 6-8 HP (4.5-6kW) per foot of machine width
- Available only in 1000 RPM PTO speed
- Screw jack for height adjustment
- Parking stands
- Choice of 3-point hitch or pull-type hitch
- Choice of straight or contoured cup flails
- 7" (178mm) diameter dynamically balanced steel flail mounting tube

Sizes–ft. (m)	15 (4.6)
Weight–lbs.(kg) (Pull-type unit)	4355(1975)
Cutting width-inches (mm)	183(4648)

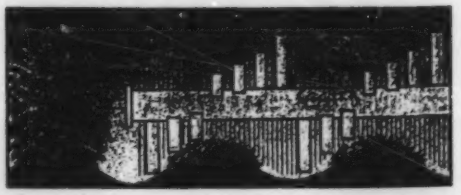
Potato Shredder/Deviner



Designed and built exclusively for the potato industry, the Alloway Potato Deviner/Shredder can reduce, even eliminate, the need for chemical defoliant. Units are available in 4, 6 and 8-row widths.



Special rollers pack foliage on top of the hill to protect potatoes against frost or sunburn. Rollers also firm up the hill and precisely control operating height.

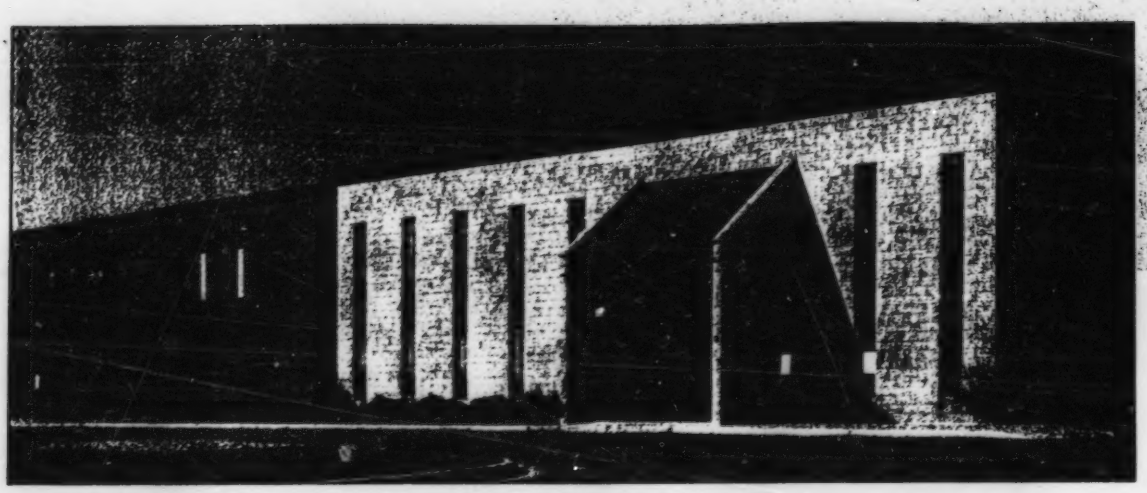


Cup flails are contour-mounted on the flail tube to deliver superior shredding performance.

Features Include

- 4, 6 and 8-row widths available
- Contour mounted cup flails
- Bed cone rollers
- 3-point or pull-type hitch
- Choice of center gearbox drive or end drive models
- Parking stands
- Screw jack for height adjustment
- 6-8 HP (4.5-6kW) required per foot of machine width
- 1000 RPM PTO speed
- 7" (178mm) diameter dynamically balanced steel flail mounting tube

Sizes–ft. (m)	12 (3.7)	15 (4.6)	18 (5.5)	20 (6.1)	24 (7.3)
Weight–lbs.(kg) (3-point unit)	3970(1801)	4230(1919)	5130(2327)	5385(2443)	6520(2957)
Cutting width-inches(mm)	143(3632)	183(4648)	215(6274)	247(6274)	287(7290)



Pioneers in the Industry

Since Alloway began as a small, family-owned business in 1946, it has grown to become a major innovator, designer and manufacturer of shortline agricultural tools and equipment. Located in the heart of North America's farming belt in Fargo, North Dakota, Alloway continues to pioneer the industry as trends shift toward higher technology.

Today, as a part of Woods Equipment Company headquartered in Oregon, Illinois, Alloway has the added support of a nationwide network of dealers while remaining committed to designing and producing the finest grain handling equipment, row crop cultivators, shredders, defoliators and snowblowers available.

See Your Woods Dealer For These Fine Products

Portable Augers • Flail Shredders • Row Crop Cultivators
Beet Defoliators • Snowblowers

Oregon, IL
815-732-2141

WOODS

Due to continual improvements, Alloway's designs and specifications are subject to change

FEMA

4995M

AMAC

AMAC-LK

HAULMTOPPERS

AMAC haulmtoppers are distinguished by their solid construction and great versatility. Large covered openings in the frame enable easy access for services and maintenance. The flails on all modells are single-piece moulded hardened steel. This ensure extensive durability. Furthermore, all haulmtoppers conform to the most stringent of safety requirements.

AMAC-LK4
4-row haulmtopper

FEATURES
- Rearmounted
- Wide suction-flails over the ridge
- Split flail rotor, driven both sides
- Changeable 3-point linkage
- Row distance 70/75 or 80/90 cm
- Haulm-dividing plates

OPTIONAL
- Conversion-kit for front mounting
- Kit for trailed transport

AMAC-LK4/COMBI
4-row haulmtopper

FEATURES
- Technical equiped as LK4, working width 3.15 m
- Front- or rear-mounted by easy changeable 3-point linkage
- Big haulm-dividing plates
- Heavy-duty support wheels
- Extra front PTO-shaft 1000r/min with free-wheeling clutch

OPTIONAL
- Extra haulm-dividing plates for optimum handling in seed potatoes

AMAC-LK2
2-row haulmtopper

FEATURES
- Front- or rear-mounted equiped
- With hydrostatic drive for ZM2 or PTO-drive
- 1 or 2 support-wheel
- Deep hood for optimum flail-length difference
- Row-distance 75/90 cm
- Haulm-dividing plates

AMAC-LK2Z
2-row haulmtopper with side-discharge

FEATURES
- Front mounted
- With hydrostatic drive for ZM2 or PTO-drive
- Very wide rotor for a clean next-row
- Row-distance 75/90 cm

AMAC-LKU
haulmtopper for beds

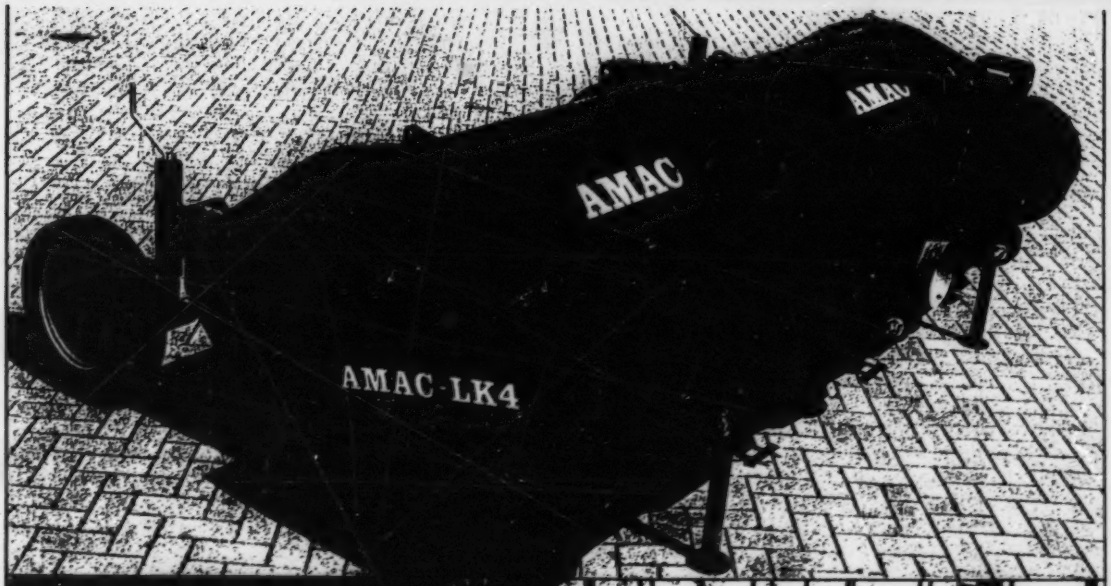
FEATURES
- Front mounted
- With hydrostatic drive for ZM2 or PTO-drive
- Side-discharge web with guiding-plate

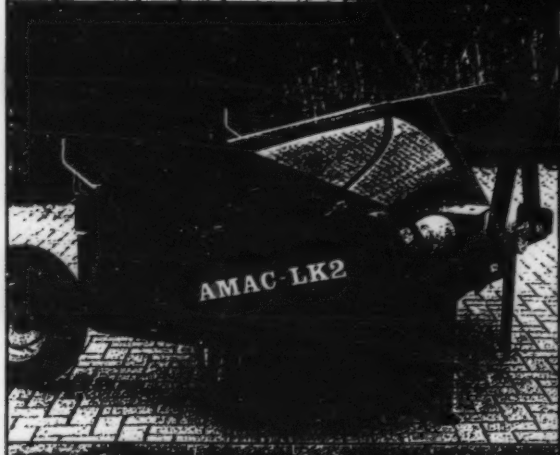
OPTIONAL
- 2 or 3 special rotors for extra cleaning
- Working-width 1,5 of 1,7 or 1,9 m
- Automatic or electric depth-control

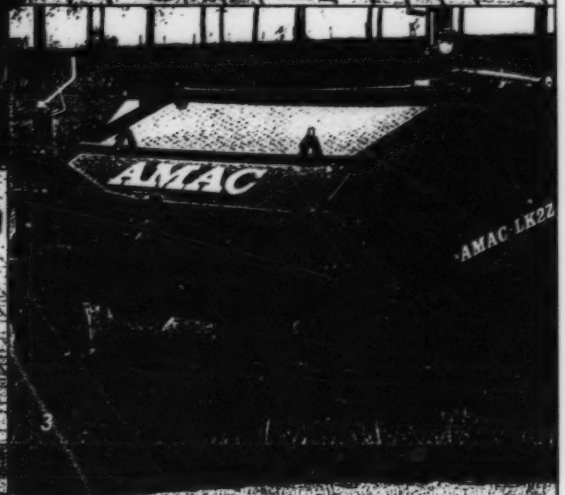
AMAC-LKZU
haulmtopper with off-set

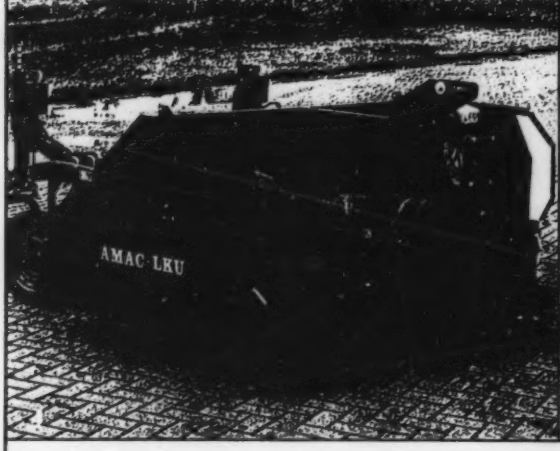
FEATURES
- Special trailed chassis
- Hydraulically folded for road-transport
- Hydraulic adjustable depth-control
- Heavy-duty stainless-steel hood and door
- Side-discharge web

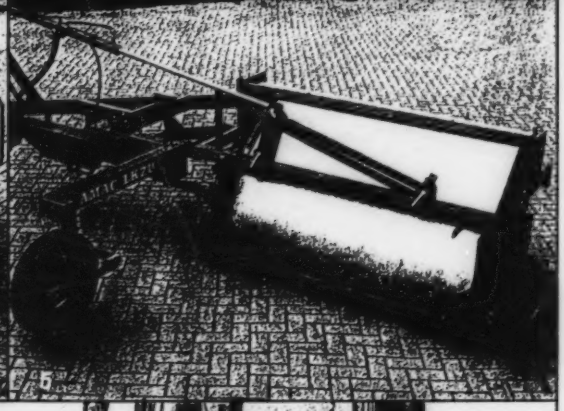
1) LK4 2) LK2 3) LK2Z 4) LKU
5) LKZU 6) LK4/Combi


AMAC
AMAC-LK4


AMAC-LK2

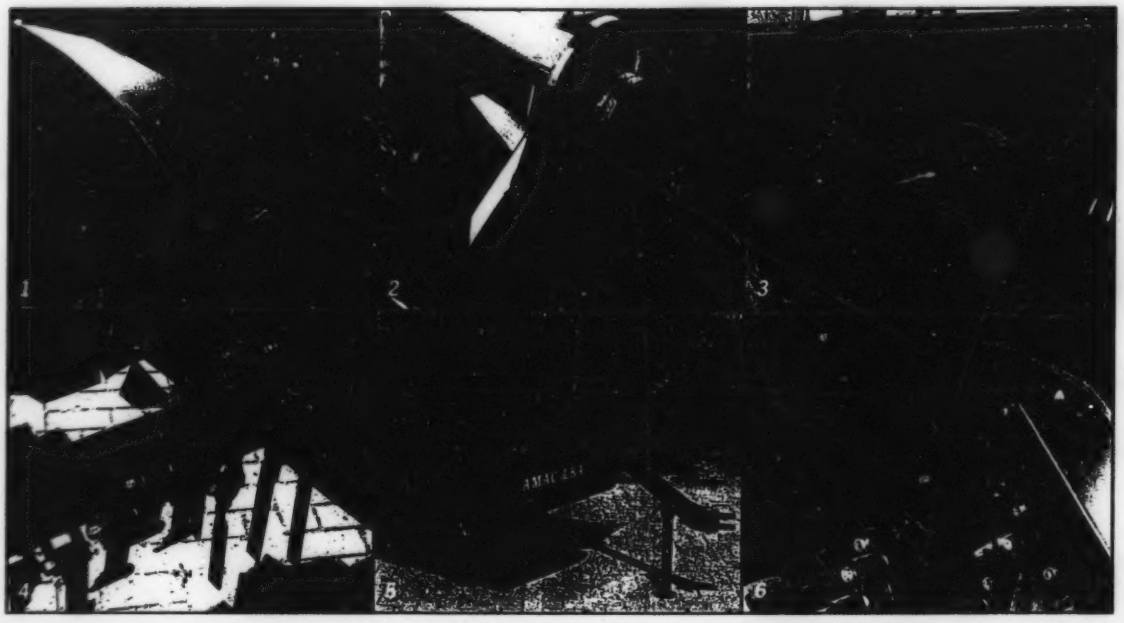

AMAC
AMAC-LK2Z


AMAC-LKU



AMAC
AMAC

HAULM TOPPERS



1) Haulm-dividing plate (Combi) *2) Front PTO-drive (Combi)* *3) Two-sided driven rotors*
4) Heavy-duty flail mounting *5) Draw-bar for trailed transport** *6) Extra haulm-dividing plates**

**Option*

TECHNICAL DATA	LK4	LK4/90	LK2	LK2Z	LKU/1,5	LKU/1,7	LKU/1,9	LKZU
Length (cm)	260	260	228	270	175	229	229	140
Width (cm)	355	403	219	260	215	235	255	250
Height (cm)	132	132	132	133	115	115	115	105
Working-width (cm)	315	360	190	190	150	170	190	170
Rows	4	4	2	2	—	—	—	—
Weight (kg)	790	840	470	610	410	500	640	800
Tyres	6.40 x 13	6.40 x 13	n.k.	n.k.	4.00 x 12	4.00 x 12	4.00 x 12	—
Flail-length difference (cm)	18 / 22	18 / 22	18 / 22	15	—	—	—	—
no. of flails	84	96	50	50	42	46	50	46
Linkage	CAT II	CAT II	CAT I	CAT I	CAT I	CAT I	CAT I	—
PTO-front	1000	1000	*	*	*	*	*	—
PTO-trailed	540	540	540	—	—	—	—	540

* mechanical with free-wheeling clutch or hydraulic driven.

AMAC

DEALER:

APPENDIX III

Appendix III

Grower Survey

Producer ID	potatatoes	Make	Year	# rows	Length of time used (years)	Tractor HP	speed (mph)	use (hrs/yr)	use (acres/yr)	height above ridges (in)	dessicant
A	both	Alloway	1999	4	2	200	3.5		600	1	before
B	seed	Alloway	1996	6	0.5	160	3.25		115	3.5	after
C	seed	Alloway	?	4	1	140	4		230	2	after
D	seed	Alloway	1997	6	4.5	180	4.25		850	2	before
E	seed	Alloway	1997	6	4	190	3.75		750	3.5	before
F	table	Alloway	2000	6	1	110	5		260	1	before
G	seed	Alloway	1992	6	2	180	2.9		150	1	before
H											
I	seed	Amac	1990	4	11	75	2.5		250	5	after
J	seed	Amac	?	2	3	100	4		100	3.5	after
K	table	chain type	old	2	2	60	5.5		80	0	no
L	seed	chain type	old	2	5			0	0		only
M	seed	corn flail	old	2	2.5	50	1.5		50	3	after
N	seed	John Deere	1999	2	2	64	3	30	20	-1	no
O	seed										
P	seed										
Q	table										
R	table										
S	seed										
T	seed										
U	seed										

Producer ID	Maintenance (hr/yr)	breakdowns (#/yr)	parts1	cost1 $	time1 (min)	parts2	cost2 $	time2 (min)	durability rating	Comments
A	11	1			10				8	2 identical flailers, broken flails not included in breakdowns
B	6									hadn't used it yet
C	2	0							9	
D	17		flail	8	5				8	
E	3	15	flail	12	10	gearbox	1800	1800	8	
F	2	0							8	
G	1	0							9	he sold it
H										
I	2	0							10	
J	6	6	flail	0	10	bearing		60	8	6 breakdowns were flails
K	6	1	chain	1	180	universal joint	50	120	10	
L										never used it

Producer ID	Maintenance (hr/yr)	breakdowns (#/yr)	parts2	cost1 $	time1 (min)	parts3	cost2 $	time2 (min)	durability rating	Comments
A	2.599657827	2.577896138			121.3547				9.6	3 identical flailers, broken flails not included in breakdowns
B	2.177074423	2.531291611			133.2266				9.74	hadn't used it yet
C	1.754491018	2.484687084							9.88	
D	1.331907613	2.438082557	flail	-1.64	156.9704				10.02	
E	0.909324209	2.391478029	flail	-2.96	168.8424	gearbox	-1700	-383.08	10.16	
F	0.486740804	2.344873502		-4.27	180.7143				10.3	
G	0.064157399	2.298268975		-5.58	192.5862				10.44	he sold it
H	-0.358426005	2.251664447		-6.89	204.4581			-1165.4	10.58	
I	-0.78100941	2.20505992		-8.21	216.33				10.72	
J	-1.203592814	2.158455393	flail	-9.52	228.202	bearing		-1686.9	10.86	7 breakdowns were flails
	-1.626176219	2.111850866		-10.8	240.0739			-1947.7	11	

Producer ID	Method last year	vine issues	# rows	Comments
A	spray and flail	no	4	tries different combinations of top killing. occasional problems from roots
B	spray only	major	2	dessication did not work well, potatoes stayed on vines and went over the end of the harvestor.
C	flail then spray	no	2	
D				
E				
F	spray then flail	minor	2	when moist, occasional wrapping occurs. Vines wrapping on drive shafts.
G	spray then flail	no	2	
H				
I	flail then spray	no	2	
J				
K	spray only	no	2	when there is trash (ie. Wild oats) he flails instead of spraying
L	spray only	minor	1	when moist, it is difficult to feed harvester
M				
N	flail only	minor	1	Russet burbank cause plugging of harvester
O	spray and flail	major	2	tries different combinations of top killing. when moist, vines wrap.
P	spray only	minor	2	need to separate mainly weeds going with potatoes
Q	spray only	no	2	uses a vine roller before dessication
R	spray only	no	2 and 4	
S	spray only	major	2	desication did not work well (too dry). Vines wrap on drive shafts.
T	spray only	major	2	potatoes don't separate from vines. Vines get carried with potatoes. Need graders on harvester
U	spray only	major	2	desication did not work well (too dry). Poor skin set.